UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
101 MARIETTA STREET, N.W.
ATLANTA, GEORGIA 30323

Report Nos.: 50-325/88-02 and 50-324/88-02

Licensee: Carolina Power and Light Company
P. O. Box 1551
Raleigh, NC 27602

Docket Nos.: 50-325 and 50-324 License Nos.: DPR-71 and DPR-62

Facility Name: Brunswick 1 and 2

Inspection Conducted: January 11-15, January 19-22, and January 31 thru February 5, 1988

Inspector: J. L. Coley 3-2-88
J. L. Coley Date Signed

Approved by: 3/7/88
J. J. Blake, Chief Date Signed
Materials and Processes Section
Division of Reactor Safety

SUMMARY

Scope: This routine, unannounced inspection was in the areas of inservice inspection (ISI) of welds, piping and components for integranular stress corrosion cracking (IGSCC), weld overlay repair welding, review of mechanical stress improvement process (MSIP) activities, and independent inspection activities.

Results: In the areas inspected, violations or deviations were not identified.

REPORT DETAILS

1. Persons Contacted

Licensee Employees

*W. Biggs, Construction Engineer
S. Connelly, ISI Specialist
**J. Davis, Chemist
*C. R. Dietz, General Manager
***E. R. Eckstein, Technical Support Manager
***K. E. Enzor, Director, Regulatory Compliance
P. Gore, Technical Support Engineer
**R. J. Groover, Project Construction Manager
*R. E. Helme, Director, On-Site Nuclear Safety
***J. R. Holder, Outage Manager
**P. W. Howe, Vice President Brunswick Nuclear Plant (BNP)
*L. E. Jones, Director, Quality Assurance and Quality Control
*R. Jordan, Construction Engineer
C. Patterson, ISI Specialist
*L. W. Wheatly, Project Specialist, Inservice Inspector (ISI)
B. White, Chemist
*M. A. Worth, Principal Engineer ISI
**T. H. Wyllie, Manager, Engineering and Construction

Other licensee employees contacted included construction craftsmen, engineers, technicians, operators, mechanics, security force members, and office personnel.

Other Organization

General Electric Company:
T. L. Brinkman, ISI Project Manager
T. R. Brinkman, ISI Level III Examiner
A. D. Ketcham, Site Services Manager
M. Krouse, Welding Foreman

NRC Resident Inspector

** W. Ruland, Senior Resident Inspector

*Attended exit interview January 22, 1988
**Attended exit interview on February 5, 1988
***Attended exit interviews on January 22 and February 5, 1988

2. Exit Interview

The inspection scope and findings were summarized on January 22 and February 5, 1988, with those persons indicated in paragraph 1. The inspector described the areas inspected and discussed in detail the inspection findings. Dissenting comments were not received from the licensee. Although proprietary material was review during the inspection, proprietary information is not contained in this report.

3. Licensee Action on Previous Enforcement Matters

This subject was not addressed in the inspection.

4. Unresolved Items

Unresolved items were not identified during this inspection.

5. Inservice Inspection

By letter dated October 2, 1987, Carolina Power and Light (CP&L) Company informed the Nuclear Regulatory Commission (NRC) of their current plans to perform intergranular stress corrosion cracking (IGSCC) examinations on the Brunswick Steam Electric Plant Unit 2 (BSEP-2) recirculation system piping and any other service sensitive austenitic stainless steel piping which contains reactor coolant at a temperature above 200°F during power operation. The examinations were to be scheduled to be performed during the reload 7 outage of BSEP-2, which was scheduled to begin on January 2, 1988. The IGSCC examinations would be conducted in accordance with the technical guidance given in Draft NUREG-0313, Revision 2.

Personnel performing the IGSCC examinations were to be qualified in accordance with the Electric Power Research Institute (EPRI)/Boiling Water Reactors Owners Group (BWROG)/NRC Training Agreement. General Electric's (GE) automated SMART ultrasonic (UT) system will be used for the IGSCC examinations where physical clearances are allowed.

On January 12, 1988, the inspector arrived at the Brunswick facility to examine the licensee's IGSCC activities and was immediately informed of a weld crack indication in a recirculation line nozzle. The inspector reviewed the data taken by the GE SMART UT System and held discussions with CP&L's and GE's Level III Examiners.

Information obtained by the inspector revealed that a significant crack had been discovered by GE when performing the pre-mechanical stress improvement ultrasonic inspection of safe-end to nozzle weld No. 2B32-RR-12"AR-E5. The crack indication was 4.8 inches long and 85% thru-wall. The indication was running in a circumferential direction and could be detected from both sides of the inconel weld.

The crack appeared to initiate in the inconel 182 butter at the nozzle inside surface (ID) run upwards thru the SA-508 steel nozzle material, then bend back through the inconel butter on the weld prep and terminate in

the upper portion of the safe-end to nozzle inconel 182 butt weld. GE had examined this weld in 1986 using the automated SMART UT system and refracted longitudinal wave transducers designed specifically to examine welds and cast materials. However, the 1986 examinations did not reveal any indication of a crack in this weld. The crack was considered unique for the following reasons:

a. Inconel weld metal is considered fairly resistant to IGSCC and is used extensively in the reactor vessel for attaching foundations and components.

b. The crack was circumferential and had penetrated the SA-508 steel in the reactor vessel nozzle.

c. If in fact this crack had initiated since 1986, the crack growth rate far exceeded any calculated crack growth rate.

d. Ultrasonic techniques have only recently been perfected to examine inconel weld metal with the level of confidence needed to ensure crack identification, i.e. UT examinations at many other plants could have also failed to identify similar cracks.

CP&L was aware of the serious implications this crack and its repair presented. A site IGSCC Project Team was set up immediately to investigate the cause of the crack and to determine the most appropriate method of repair. The inspector reviewed data obtained during the investigation of records, held discussions with cognizant personnel and established a direct technical interface at the site for NRC management and engineering personnel at the Regional and Headquarters offices. Specific data investigated during this period consisted of the following:

- Construction weld fabrication records
- Safe end modifications records
- Construction radiographs
- Design stress analysis
- Stress analysis of the recirculation system overlay weld repairs
- ISI records for every nozzle examination conducted on Unit 1 and Unit 2 since construction
- Methods of repair and the design basis for repair

By the end of the second week, several significant findings had been established and the licensee had decided on a specific method of repair. The most significant finding was that this defect had been detected during a manual ultrasonic inspection of this nozzle weld in May of 1984. Unfortunately, at that time, ultrasonic techniques and equipment had not been used that could track the indication through the inconel weld material and the inspection personnel had evaluated the indication as an inclusion contained within the nozzle that had very little thru-wall depth and, therefore, was acceptable to the ASME Code criteria. In addition to the above, technical reviews of the 1986 examinations by GE and the

inspector revealed that, although GE used equipment capable of penetrating the inconel weld metal with a high level of confidence, certain inspection parameters were unsatisfactory. They consisted of the following:

a. Transducer sound wave angles were too shallow to allow adequate coverage

b. Fixtures for the transducers were too large and also limited the scans

c. Lift-off, resulting from the weld joint configuration and items a. and b. above, limited the effectiveness of the examination.

d. A defect in the bottom 50% of the weld would not have been detected using the 1986 techniques and equipment

The technical problems identified above are commonly encountered when advance automated equipment and techniques are substituted for manual methods and implemented by personnel without sufficient field experience. These findings prompted the inspector to review the SMART examination data for six reactor vessel nozzle welds examined on Unit 1 in 1987. The inspector discovered that GE had corrected each of the equipment and technique problems identified during the Unit 2 examinations performed in 1986 and had conducted reliable examinations on Unit 1 in 1987.

Once it was determined that the crack indication had been in the weld before the 1984 examinations, the inspector's concerns regarding possible errors in the recirculation system stress calculations and accelerated crack growth rates were diminished. Concern now focused on what caused the circumferential crack in inconel material. The apparent cause of the crack was IGSCC. The concern was generic because of the uncertainty of previous ultrasonic techniques used to examine these welds and the fact that two other reactors (one in the USA and one overseas) had recently experienced cracking in their reactor vessel nozzle welds.

On January 27, 1988, Region II management personnel accompanied by the inspector attended a NRC/CP&L technical meeting at Bethesda, Maryland. The meeting was held to discuss the Brunswick Unit 2 crack on Weld No. B32-RECIRC-12"-AR-E5, CP&L's investigation and propose method of repair. The CP&L presentation covered the following:

I. Current Unit 2 Status - Presentation made by GE
   A. Characterization of Defect
   B. Review of Previous Examinations

II. History of Weld Joint 12"-ARE5 - Presentation Made by CP&L Corporate Welding Engineer
   A. Review of Film
   B. Review of Weld Travelers

III. Metallurgical Aspects - Presentation Made by GE
   A. Crack Growth
   B. Smooth Appearance
   C. Additional Stresses Induced by Local Weld Overlays
   D. Conclusion that indication is IGSCC

IV. Repair Method - Presentation by CP&L and Structural Integrity Associates
   A. Repair Selection Basis
   B. Discussion of Inconel Overlay Application
   C. Future Inspectability of Weld Overlay Repair

V. Additional Mitigation Activities - Presentations by CP&L and GE
   A. Hydrogen Water Chemistry
   B. Crack Arrest Verification (CAV)

The technical information was presented in a very informative manner. The exchange of questions between the NRC and CP&L representatives was excellent. The technical exchange was unquestionably beneficial to the NRC and CP&L.

On January 28, 1988, Region II was informed, by NRC Headquarters personnel, that cracks had been reported in both manway covers in the reactor shroud at Peach Bottom. The cracks were in inconel material, approximately 50% thru-wall and extended intermittently around the entire circumference of the manway covers. Region II was also informed that GE would be performing the shroud manway inspection at Brunswick Unit 2, starting on January 31, 1988.

The inspector arrived at Brunswick facility on January 31, 1988. Modification work on GE's remote scanner device and SMART system calibrations were witnessed by the inspector until Wednesday night, February 3, 1988, when the reactor vessel became available for inservice inspection. GE worked continuously for seventeen hours before successfully placing the remote device on the first manway cover. Each cover was to be inspected twice; once with a 60° refracted longitudinal wave transducer to examine the inconel weld material and to accurately size deep cracks with crack tip detection techniques. The second examination was to be performed with a 45° shear wave transducer to detect smaller corner reflectors in the inconel manway covers. By Friday, January 5, 1988, data had been taken on both manway covers using both inspection techniques and the preliminary evaluations appeared to indicate that Brunswick Unit 2 did not have any cracking in the inconel manway covers.

During the three weeks that the inspector was at the Brunswick facility, many other outage work activities were also examined by the inspector including other ISI activities. These activities are delineated below:

a Review of ISI Procedures - Unit 2

The inspector reviewed the licensee's outage plan for examination of IGSCC during the Winter 1988 outage. The inspector also selected the following GE Procedures for technical review because they dealt specifically with the examinations that were in process and the unique equipment required to accomplish these examinations:

Procedure Number	Procedure Title
NDE-1, R-1	Review Process and Analysis of Recorded Indications
NDE-9, R-0	Procedure for Operational Guidelines with "SMART UT System"
NDE-30, R-15	Procedure for the Ultrasonic Examination of Austenitic Metal Welds for IGSCC
NDE-35, R-6	Procedure for Ultrasonic Planar Flaw Sizing
UT-43, R-9	Procedure for Ultrasonic Examination of Pipe Welds Using Automated Equipment
UT-31, R-9	Procedure for Manual UT Examination of Weld Overlayed Austenitic Piping
UT-57, R-0	Remote Ultrasonic Examination Procedure for Detection of IGSCC in Shroud Support Access Coverplate
UT-46, R-3	Procedure for Ultrasonic Examination of Weld Overlayed Austenitic Piping Using Automated Equipment
UT-51, R-2	Procedure for Automated Ultrasonic Examination of Dissimilar Metal Welds
UT-52, R-2	Procedure for Automated Ultrasonic Examination of Thermal Sleeve Attachment Welds on Recirculation Inlet Safe-Ends
UT-53, R-1	Procedure for Manual Ultrasonic Examination of Dissimilar Metal Welds
PT-90.1 and PT-90.5	In-Core Visual Examination

The inspector reviewed the above procedures to determine if requirements specified agreed with licensee's commitments, qualification of NDE personnel was specified, methods of examination were adequately described and methods for recording, evaluating and dispositioning findings were established.

Within this area of examination, no violations or deviations were identified.

b. Observation of Ultrasonic Work Activities and Evaluation of Recorded Data - Units 1 and 2

The inspector observe ISI work activities, reviewed and evaluated SMART system data for the following inconel buttered reactor vessel nozzle welds on Unit 2:

	Weld No.	Config.	Procedure	ISO. DWG	CAL BLK
(1)	2B32-RR-28A-1 NOZZLE SIDE	NO22.	UT-43	19-1	58B
	2B32-RR-28A-1 N-SE & S-END SIDE	N-SE	UT-51	19-1	002
		S-END	UT-43	19-1	48B
(2)	2B32-RR-28B-1 NOZZLE SIDE	NOZ2.	UT-43	20-1	58B
	2B32-RR-28B-1 N-SE & S-END SIDE	N-SE	UT-51	20-1	002
		S-END	UT-43	20-1	46B
(3)	2B32-RR-12"AR-A5 NOZZLE SIDE	SE-N	UT-51	21-1	83B
	2B32-RR-12"AR-A5 SAFE-END SIDE	S-END	UT-43	21-1	49B
(4)	2B32-RR-12"AR-B5 NOZZLE SIDE	SE-N	UT-51	21-1	83B
	2B32-RR-12"AR-B5 SAFE-END SIDE	S-END	UT-43	21-1	49B
(5)	2B32-RR-12"AR-C5 NOZZLE SIDE	SE-N	UT-51	21-1	83B
	2B32-RR-12"AR-C5 SAFE-END SIDE	S-END	UT-43	21-1	49B
(6)	2B32-RR-12"AR-D5 NOZZLE SIDE	SE-N	UT-51	21-1	83B
	2B32-RR-12"AR-D5 SAFE-END SIDE	S-END	UT-43	21-1	49B
(7)	2B32-RR-12"AR-E5 NOZZLE SIDE	SE-N	UT-51	21-1	83B
	2B32-RR-12"AR-E5 SAFE-END SIDE	S-END	UT-43	21-1	49B
(8)	2B32-RR-12"BR-F5 NOZZLE SIDE	SE-N	UT-51	22-1	83B
	2B32-RR-12"BR-F5 SAFE-END SIDE	S-END	UT-43	22-1	49B
(9)	2B32-RR-12"BR-G5 NOZZLE SIDE	SE-N	UT-51	22-1	83B
	2B32-RR-12"BR-G5 SAFE-END SIDE	S-END	UT-43	22-1	49B
(10)	2B32-RR-12"BR-H5 NOZZLE SIDE	SE-N	UT-51	22-1	83B
	2B32-RR-12"BR-H5 SAFE-END SIDE	S-END	UT-43	22-1	49B

Weld No. (cont'd)	Config.	Procedure	ISO. DWG	CAL BLK
(11) 2B32-RR-12"BR-J5 NOZZLE SIDE	SE-N	UT-51	22-1	83B
2B32-RR-12"BR-J5 SAFE-END SIDE	S-END	UT-43	22-1	49B
(12) 2B32-RR-12"BR-K5 NOZZLE SIDE	SE-N	UT-51	22-1	83B
2B32-RR-12"BR-K5 SAFE-END SIDE	S-END	UT-43	22-1	49B

Two new crack indications were revealed as a result of the above examinations. The first and most critical indication was the circumferential crack in weld 2B32-RR-12"-AR-E5. This crack will require an inconel overlay weld repair. The program and method of repair will be discussed in subsequent paragraphs below. The second new crack indication was an axial crack discovered in Weld No. 2B32-RR-28-B1. This was the second axial crack found in Weld No. 2B32-RR-28-B1 since the 1986 inspection of this weld had also detected a crack. Re-examination of the 1986 detected crack revealed no measurable growth to the previously recorded crack.

In addition to the inspector's evaluation and examination overview of the above reactor vessel nozzle welds the inspector also witnessed portions of the UT examinations for IGSCC and reviewed SMART System data for the following piping and component welds:

Weld	Procedure	Configuation
*- 2B32-RR-12"-AR-D2	UT-43	Pipe to Elbow
**- Inconel Manway Cover @ 0° In Reactor Vessel Shroud Base Plate	UT-57	Structural Butt Weld
**- Inconel Manway Cover @ 180° In Reactor Vessel Shroud Base Plate	UT-57	Structural Butt Weld
- 2B32-RR-AM-1	UT-43	Valve to Pipe
- 2B32-RR-AR-E1	UT-43	Fitting to Pipe

Note *Examination data for Weld No. 2B32-RR-12"-AR-D2 was reviewed by the inspector to confirm a reported axial crack in this weld.

**The UT examinations of the reactor vessel shroud manway covers at 0° and 180° in the Brunswick Unit 2 vessel revealed no crack indications.

The inspector reviewed GE's personnel certifications for the following examiners to determine if the method and level of examiner qualifications agreed with licensee commitments:

Examiner	UT	IGSCC	Sizing
S. C. A	II	II	
R. W. A	II	II	
R. U. B	II	II	
R. G. A	II	II	
R. Z. B	II	II	
J. L. B	III	II	II
T. L. B	III	II	II
T. B. B	III	II	II
P. S. A.	I		
T. D. B	I		

After reviewing the crack indications discovered during the present examinations on Unit 2, the inspector concluded that information may be available (as had been demonstrated for Weld No. 2B32-RR-12"-AR-E5) in previous examination data to determine why indications now recorded were not detected, therefore, the inspector conducted a technical review of records on Units 1 and 2 for all sixteen reactor vessel nozzles required by code to be examined. This review included the most recent examinations and historically tracked the examination process to the construction baseline. The review revealed that until 1987 automated examinations of these welds lacked adequate coverage because of weld joint geometry and inadequate equipment accessibility. In additions from 1975 to and including 1985, UT examination of these inconel buttered weld were conducted with shear wave transducers which had limited ability to penetrate the inconel weld material.

GE had corrected all examination limitations for the 1988 examinations of Unit 2. A sample of six reactor vessel nozzle welds were also examined correctly on Unit 1 in 1987 and no crack indications were observed. The licensee intents to examine the remaining ten nozzle welds on Unit 1 during the outage presently scheduled for November 12, 1988.

Within the areas examined, no violation or deviation was identified.

c. In-Core Visual Examination - Unit 2

The inspector observed GE perform the in-core visual examinations of the guide rod support brackets and plug welds. This work was conducted in accordance with PT-90.1. The inspector also reviewed video tapes of the core spray headers after cracking was reported by the licensee in the 316 stainless steel piping of the header. The crack was located in the heat effective zone of a 5" diameter pipe

weld to T-box fitting. The fitting was located in the north header at the 90° core spray nozzle inlet. The crack was approximately 2" in length. The indication will be examined with liquid penetrant and sized with UT later in the present outage to determine the full extent of the indication and the crack depth. GE is evaluating the cause of the crack and will determine whether a repair will be necessary when all the test data is available.

Within the area examined, no violation or deviation was identified.

6. Overlay Repair Welding - Unit 2 (73753 and 55050)

The inspector observed two overlay repair weld activities to determine if approved procedures were used and if personnel responsible for the performance of each activity were knowledgeable of procedural requirements.

The first activity examined by the inspector was CP&L's weld overlay repair upgrade. This program upgrades previously deposited design overlays to full structure overlays of the width necessary to insure full inspection coverage for UT. GE has been contracted by CP&L to upgrade the overlay weld repairs. However, GE was working to CP&L's approved quality assurance program and procedures. GE welder's were also qualified to CP&L welding procedure specifications. The overlay upgrade activities were conducted in accordance with plant modification (PM) 87-128 using CP&L weld procedure specification (WPS) - 8BU12 and/or Maintenance Instruction (MI) 25-33. The inspector observed the upgrade repair welding for weld No. 2B32-RR-28-B3 and weld No. 2B32-RR-28-B4. Equipment settings, calibration, instructions and welder qualification efforts were verified by the inspector for the following GE welders:

Welder

R. D.
C. R.
J. P.

The second repair activity examined by the inspector was GE's repair welding program for the inconel weld overlay repair of the circumferential crack found on the reactor vessel nozzle-to-safe-end weld No. 2B32-RR-12"-AR-E5. GE had recently made a similar repair at an oversea plant and had qualified procedures and welders to made this inconel weld repairs on SA-508 steel and inconel material. Since this repair was to be made to GE's Quality Program and procedures, the inspector reviewed the following aspects of GE welding program:

- GE's Nuclear Plant Services Department Quality Assurance Manual #161 for Modification, Maintenance; Repair or Replacement Projects

- GE's Welding Specification No. WPS-CCN-432R5 for Repair Welding P-No. 3 Base Mat'ls Using the Machine Gas Tungsten - ARC (GTAW-ME) Temper Bead Technique

- Welding Procedure Qualification Report No. CCN-432

- Welder Qualification Reports

- Equipment Certification and Calibration Records

- Welder Qualification Maintenance Records

- Mockup Welding

The above welding activities were performed in accordance with the ASME Code, Section IX, 1986 Edition and Code Case 432 for temper bead weld repairing.

Within the areas examined, no violations or deviations were identified.

7. Mechanical Stress Improvement Process Activities - Unit 2

The inspector held discussions with CP&L's cognizant engineering staff and reviewed documentation which dealt with the application and design base for mechanical stress improvement. CP&L intends to use this process on the reactor vessel nozzle to safe-end welds. The process is recognized by NRC as an effective way to minimize and control IGSCC. The inspector however, was not satisfied with the design base information available at the site for the safe-ends to reactor vessel nozzle welds on 12" inlet riser piping. The particular area of concern dealt with the anticipated hoop stress redistribution pattern for the 12" inlet riser weld versus the 10" core spray safe-end to nozzle weld.

The core spray uses a tuning fork design safe-end for the attachment of the thermal shield. This design would not be effected if the concentration of hoop stress was transferred from the weld joint and heat effective zone to the area where the tuning fork is forged to the safe-end as was the case in the design basis example the inspector reviewed. However, the 12" inlet riser safe-end weld scheduled for mechanical stress important has its thermal shield welded to the safe-end. If the hoop stress was transferred to this area, the additional stress coupled with the fact that the safe-end would be sensitized could accelerate IGSCC. The licensee assured the inspector that the stresses would not be redistributed to this area on a 12" safe-end.

The inspector requested that the licensee have someone from O'Donnell & Associates Inc., the firm that was responsible for the site technical expertise and design work on this process, to attend the NRC/CP&L technical meeting for the repair of weld No. 2B32-RR-12"-AR-E5 in Bethesda, Maryland on February 27, 1988, and to be prepared to discuss the

stress redistribution patterns for a 12" safe-end with a welded thermal shield. The licensee agreed and this matter was discussed in detail and to the satisfaction of the inspector on February 27, 1988.

Within the areas examined, no violations or deviations were identified.

8. Independent Inspection Activities Unit 2

The inspector also held discussions with cognizant engineers, reviewed work instructions and performed in-process surveillance inspection of the following licensee activities:

*(1) The licensee's Crack Arrest Verification Process activities were discussed with CP&L chemists.

*(2) The licensee's hydrogen addition modification work was discussed with CP&L's chemist and Energy Services personnel. This new installation was also walked down by the inspector from the hydrogen storage building to the point of injection into the suction side of the condensate booster pumps.

(3) Service water piping inspection and repair for the conventional header and piping. This work was being conducted in accordance with Plant Modification No. 87-208.

(4) Freeze seal applications for Plant Modification No. 86-008. This plant modification installs two new cold reference legs with new condensate chambers. These new reference legs will tie in plant instrumentation used for wide range (0" to 210") reactor water level measurements.

(5) Qualification of lifting equipment for the reactor vessel inspection platform.

*Note: Items (1) and (2) above are described in detail in Region II Inspection Report No. 325, 324/88-08

Within the areas examined, no violations or deviations were identified.